Stock Assessments for British Columbia Herring in 1983 and Forecasts of the Potential Catch in 1984

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March 1984

Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1751

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by

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Cat. No. Fs 97-4/1751 ISSN 0706-6473

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ABSTRACT

Haist, V. and M. Stocker. 1984. Stock assessments for British Columbia herring in 1983 and forecasts of the potential catch in 1984. Can. MS Rep. Fish. Aquat. Sci. 1751: ix + 50 p.

Herring stock abundance in British Columbia waters was assessed for 1983, and forecasts were made for 1984 using three methods: (1) Hourston's method, (2) age-structured model analysis, and (3) surplus production model analysis.

The abundance of the 1983 adult herring run in British Columbia waters assessed by Hourston's method was 344,000 tonnes. This is a decrease of 46,000 t (12%) from 1982. The 1984 run is forecast at 266,000 t with average recruitment. The 1984 forecasts for poor and good recruitment are 203,000 t and 375,000 t respectively. Average recruitment would provide a potential catch of 91,000 t.

The potential catch predictions from age-structured model analysis, for 1984, do not vary greatly between the "constant" and "variable" assumptions. For the B.C. coast the catch estimates are 49,700 t and 47,900 t for the "constant" and "variable" assumptions respectively.

Assuming average production the surplus production model analysis predicts a potential catch for 1984 of 162,000 t and 175,000 t for the "constant" and "variable" assumptions respectively. These unusually high catch levels result from poor model fits obtained for most of the separate stock data sets.

The recommended target quota (20% of the weighted 1984 herring run size) is 61,000 t. Under conservative management and other constraints encountered administering fisheries, the catch levels recommended herein may be substantially reduced.

Key words: Clupea harengus pallasi, Pacific herring, stock assessment, forecasts, surplus production, age-structured analysis.

RÉSUMÉ

Haist, V. and M. Stocker. 1984. Stock assessments for British Columbia herring in 1983 and forecasts of the potential catch in 1984. Can. MS Rep. Fish. Aquat. Sci. 1751: ix + 50 p.

L'importance en 1983 des stocks de hareng des eaux de la Colombie-Britannique a été évaluée et des prévisions pour 1984 ont été effectuées selon trois méthodes: 1) la méthode de Hourston, 2) l'analyse par modèle de structure d'âge et 3) l'analyse par modèle de production excédentaire.

L'importance du stock de frai de 1983 de harengs adultes dans les eaux de la Colombie-Britannique a été estimée à 344 000 tonnes par la méthode de Hourston. Cette valeur est inférieure de 46 000 t (12 %) à celle de 1982. On prévoit, avec un recrutement moyen, un stock de frai de 266,000 t tour 1984. Les valeurs de cette prévision sont respectivement de 203 000 t et de 375 000 t pour des recrutements faible et supérieur. Un recrutement moyen se traduirait par une possibilité de prises de 91 000 t.

Les prévisions de prises possibles pour 1984, obtenues par modèle de structure d'âge, sont sensiblement les mêmes pour les hypothèses "constante" et "variable". Les estimations de prises dans les eaux côtières de la C.-B. sont respectivement de 49 700 t et de 47 900 t pour les hypothèses "constante" et "variable".

Avec l'analyse par modèle de production excédentaire, et en supposant une production moyenne, on prévoit pour 1984 des prises possibles de 162 000 t et 175 000 t. Ces valeurs anormalement élevées résultent d'un mauvais ajustement du modèle à la plupart des séries de données des stocks individuels.

Le quota cible recommandé (20 % du stock de frai pondéré de 1984) est de 61 000 t. Une gestion prudente des stocks et d'autres limitations découlant de l'administration des pêches pourraient réduire ce niveau de façon appréciable.

Mots clés: Clupea harengus pallasi, hareng du Pacifique, évaluation de stocks, prévisions, production excédentaire, analyse par structure d'âge.

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FOREWORD

This report was prepared by the Herring Population Dynamics Program of the Herring/Shellfish Section (Fisheries Research Branch), and contains proposed catch levels for herring for the 1983/84 season. These recommended catches are based primarily on biological considerations, and may vary with those finally adopted by the Herring Stock Assessment Committee. The final fishing plans adopted by Fisheries Management will be based not only on biological considerations, but also economic and social, enforcement, and other factors.

Results contained in this report were presented to the Herring Stock Assessment Committee in August of 1983.

ACKNOWLEDGMENTS

This document not only presents the efforts of the Population Dynamics Program but numerous other members of the Herring Section staff play key roles in collection and processing of data. The ages of herring from the 1983 samples were determined by Margret Burke of the Pacific Biological Station Ageing Unit. Also, Field Services personnel and contractors contribute to this effort.

1. INTRODUCTION

1.1 General

Forecasting the potential catch that can be removed from herring stocks requires assessing the status and determining which factors affect stock dynamics. Traditionally, yield models have assumed equilibrium conditions implying no changes in age structure, growth, or mortality over time. However, herring are strongly affected by changes in conditions thus making equilibrium models unattractive. The methods we use try to estimate current stock conditions on the basis of which potential catches are recommended that will not have deleterious effects on the stocks.

In this report we present three methods to assess herring stock conditions: (1) Hourston's method (Hourston and Schweigert 1981), (2) age-structured model analysis (Fournier and Archibald 1982), and (3) surplus production model analysis. The first two methods use age composition data, and all three methods use spawn deposition information.

1.2 Data Base

The main data inputs for these stock assessment methods are spawn survey data, commercial catch landing data, and age composition data from biological samples of commercial catches, pre-fishery charters, and research cruises. These data are available on computer files in a consistent format for the period 1951 to 1983. This time span includes the reduction fishery period to 1968 and the subsequent "roe" fishery period starting in the early 1970s.

Of the three sets of information the spawn data has the largest measurement errors. We feel that the quality of spawn surveys has improved greatly over the 33-year span of these observations. This improvement is a result of increased numbers of people and vessels being involved in spawn surveys, increased attention to data measurements, increased coverage of subtidal spawnings, and increased research on estimating egg deposition from spawn observations. Hourston's method has attempted to utilize the increased accuracy of the spawn data by incorporating more sophisticated formulas for estimating egg deposition from survey information as more detailed data were collected. The only consistent observations made during the entire 33 years of spawn surveys are the length, the width, and a measure of intensity of spawnings. The surplus production and age-structured models use a spawn index calculated by summing the length times the intensity of all spawnings in an area. Observations on width are not used in these two models because they probably have greater measurement errors as people were unaware of subtidal spawnings in the earlier years. The two models evaluate the implications of time dependent trends in the spawn index.

Catch information was obtained from landing slip data. Hourston's method uses only roe fishery catch data for the period 1972-83. The other two methods use all landing slip data for the season (seasons run from July 1 to June 30). The 1982/83 catch figures are based on hailed estimates because

sales slip data were not available for timely analysis. The sales slips record catch in tons. Numbers of fish in the catch, for use in the age-structured model, were calculated using the average fish weight from catch samples for the season. A small amount of catch obtained off the west coast of Vancouver Island during the reduction period is not included in the W.C.V.I. data set, but is included in the data for the entire south coast. These fish, caught offshore in the summer, could be either west coast or Strait of Georgia spawners.

Age structure data is used in both Hourston's method and in the age-structured model. For the age-structured model all catch samples from a geographical area are used in the estimate of proportion at age for the period of reduction fisheries. However, the various fisheries since the early 1970s have different age selectivities so the age structure samples have been weighted by the relative amounts of catch for each type of fishery (gillnet roe, seine roe, other). Hourston's method uses age structure information which is compiled by section (see Hourston and Hamer 1979 for section definitions) and week for each fishery. The age structure of the spawning populations is estimated from seine sampling data.

Additional information obtained from the biological sampling data base is used in Hourston's method and in the age-structured model. This includes data on age specific fecundities, fish weights, and percent females.

1.3 Stock considerations

For Hourston's method (Section 2) stock assessments are conducted separately for each management unit (Hourston and Hamer 1979). These geographic regions (Fig. 1.1) support or have the potential for roe fisheries and include the spawning ground utilized by the fish (Hourston 1982).

For the age-structured model analysis (Section 3), and the surplus production model analysis (Section 4) stock assessments are conducted separately for each of seven data sets. Two of these group the entire north and the entire south into two separate "stocks". The other five data sets (Fig. 1.2) look at three "stocks" in the north (Queen Charlotte Islands, north coast, central coast), and two "stocks" in the south (west coast of Vancouver Island, Strait of Georgia and Johnstone Strait). These stock groupings are a re-definition of the management unit stock concept. The assumption that spawners return to the same management unit in which they previously spawned has been relaxed in this re-definition. The five geographic regions are more in line with west coast herring populations that were originally identified on the basis of mean vertebral number (Tester 1937, 1949), and the division level of data aggregation (Hourston and Hamer 1979).

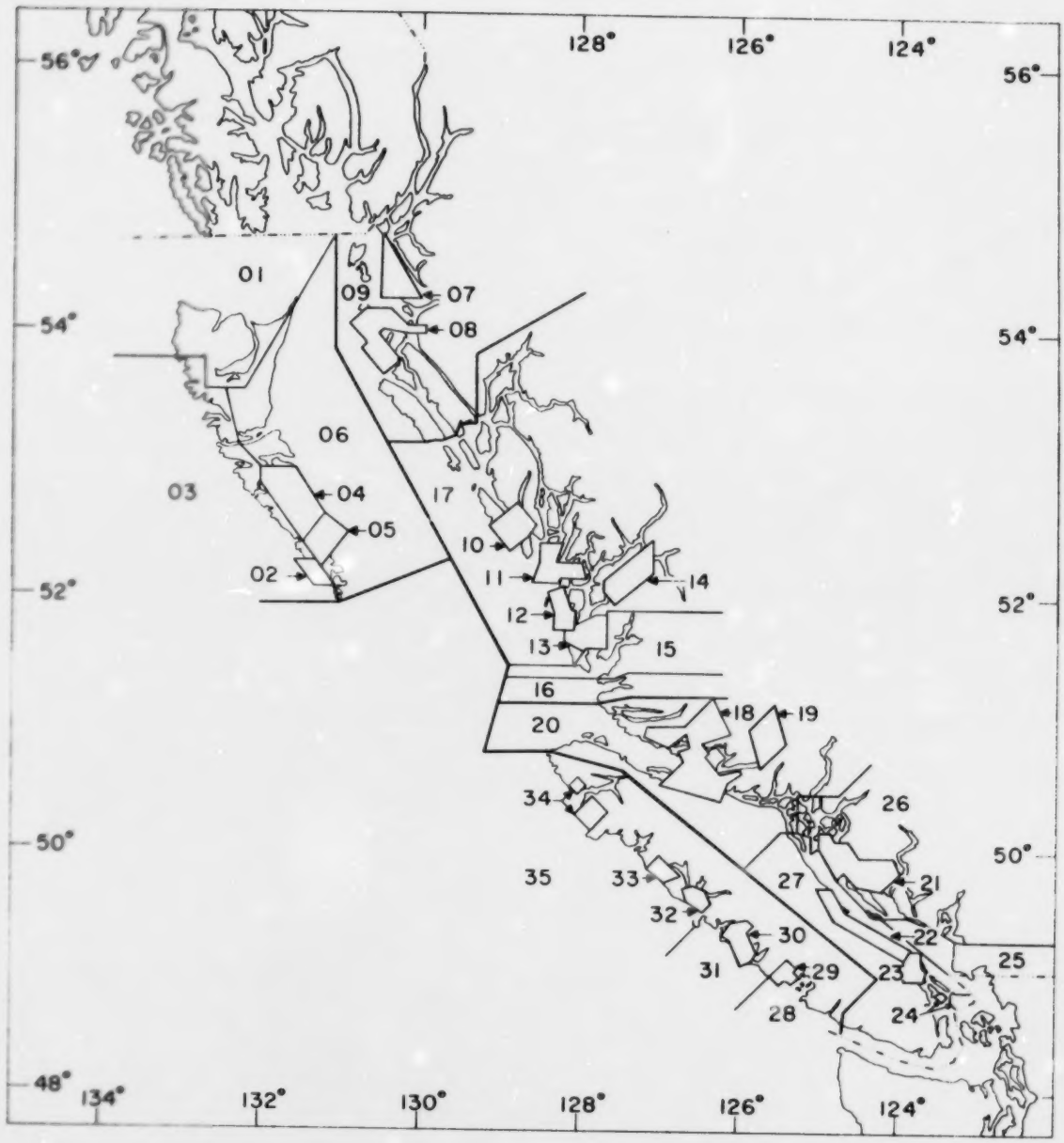

Fig. 1.1. Management units for British Columbia herring roe fisheries.

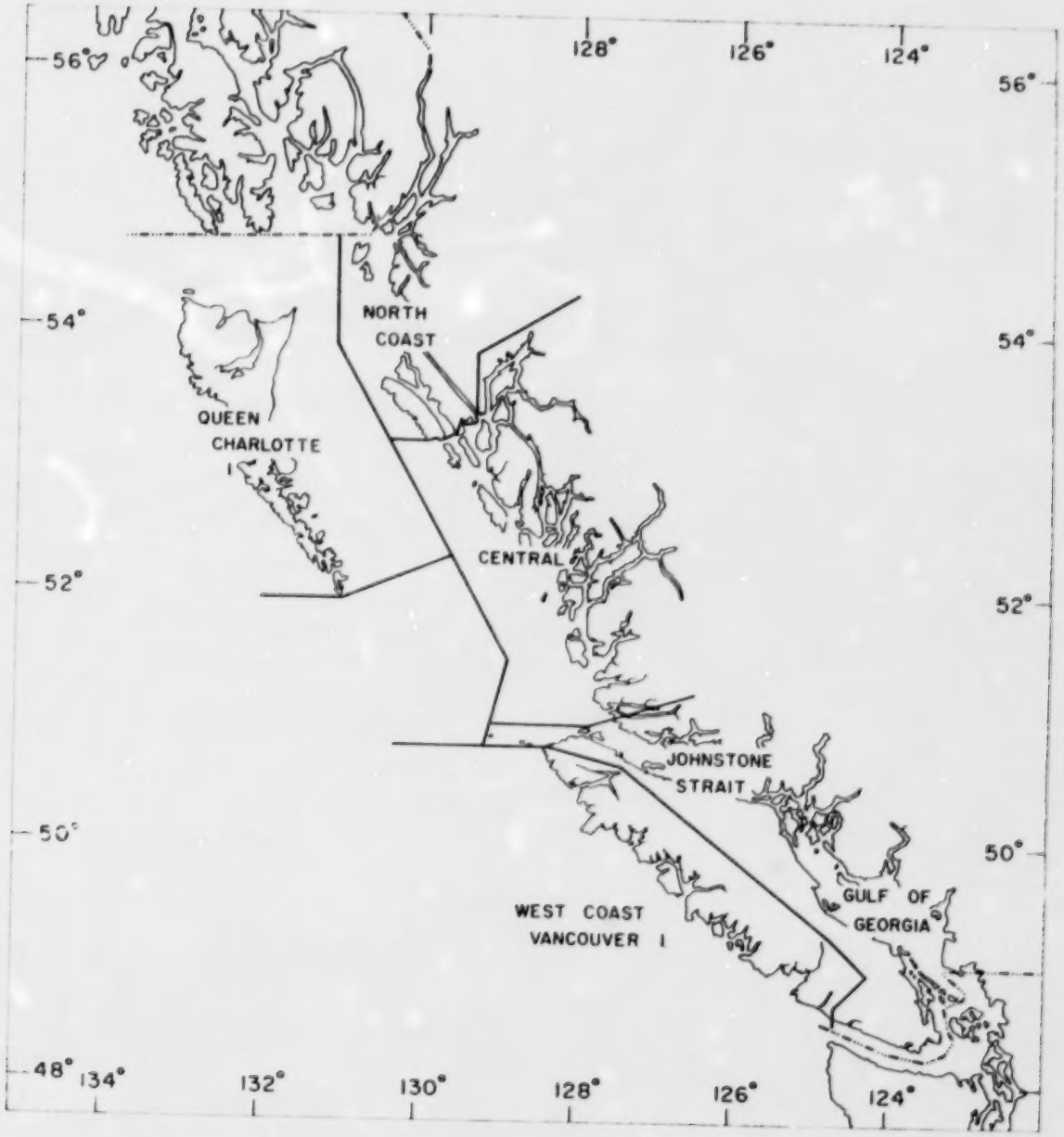

Fig. 1.2. Herring stock groupings for age-structured model analysis, and surplus production model analysis.

2. HOURSTON'S METHOD

2.1 Introduction

Hourston's method for assessing and forecasting stock abundance was developed explicitly for the B.C. herring roe fisheries. The roe fisheries, which developed through the early 1970s, occur on geographically segregated areas at virtually the same time which resulted in the need for quantitative forecasts for each potential fishery. To assess and forecast stock abundance a computer analysis was developed which incorporates catch, spawn deposition, and sampling data (Hourston and Schweigert 1981).

The analysis is set up in two parts - the assessment of spawning stocks in a given year, and the forecast of runs in the following year. Spawning stock abundance is primarily dependent on the estimates of egg deposition calculated from fishery officer spawn surveys. Forecasts to management units have two components. First, the estimate of adults (repeat spawners) obtained from applying survival rates at age (Tester 1955) to the previous year's spawning stock. Second, the estimate of recruitment which is an average estimated for the stock in previous years.

Potential catch is forecast for each management unit by subtracting the desired escapement from the forecasted run. Desired escapements have been set at levels that have historically provided better than average recruitment. In previous analyses using this method potential catch for each division was calculated by summing the predictions for each management unit within the division. However, for this analysis potential catch at the division level was calculated by subtracting the desired escapement for the entire division from the forecasted run. Thus, if the desired spawners are not available in one management unit they will be compensated for elsewhere in the division.

The forecasting analysis involves two basic assumptions. Firstly, that adults return to the same management unit, or that immigration balances emigration in a management unit. Secondly, that all 3-yr old and younger fish are new recruits, and all 4-yr old and older fish are repeat spawners. Neither of these assumptions is likely to be met for all management units (Hourston 1981).

2.2 Methods

Only a brief description of this stock assessment method is given here, as detailed accounts have been published elsewhere (Hourston and Schweigert 1981).

The spawn data collected by fisheries officers (F.O.) in recent years includes area of spawn, layers of eggs, and percent contribution of various substrates. These are converted to estimates of egg deposition using tables of eggs per unit area for the substrates (Haegele et al. 1979) and dividing by egg correction factors for the area. The egg correction factors

are included to account for bias in F.O. surveys and incomplete coverage of areas. Correction factors have been updated using adjustments determined from comparing F.O. surveys to diver surveys for areas of dual coverage in 1981 (Table 2.1).

The number of spawners at age in an area is calculated using age composition, percent females, and fecundity information from sample data along with the estimates of numbers of eggs deposited. The forecast of returning adults in the coming year is then determined by applying age-specific survival rates according to Tester (1955) as follows:

Age	3	4	5	6	7	8	9
Survival rate	0.6839	0.6005	0.5273	0.4630	0.4066	0.3570	0.3135

Recruits to the spawning stock are assumed to be all 3-yr old fish and younger. Using recruitment estimates for the period 1972-1983 three levels of recruitment are calculated using the average for the lowest 25%, all, and the highest 25% of the years.

2.3 Status of stocks

2.3.1 North

Estimates of spawners and hailed roe catches in 1983 and of total pre-fishery abundance for the period 1974-83 for the northern management units and divisions are shown in Table 2.2. The 1983 pre-fishery biomass for the Queen Charlotte Islands was estimated at 32,500 tonnes. This represents a 23% decrease from the 1982 pre-fishery biomass. All management units in this division show a decrease in stock abundance over the previous year with the exception of Area 2W stocks. For the north coast division the estimated pre-fishery biomass was 38,000 t which is an increase of 95% over the previous year. The north coast stocks appear to have recovered to average levels observed in the early and mid 1970s. The central coast pre-fishery biomass for 1983 was estimated as 53,500 t. This is virtually no change from the 1982 estimate and indicates stocks are at the highest level for the 10-year period.

Generally, the northern stocks appear to be in good shape with 1983 pre-fishery abundances as high as or above the average observed in the previous 10 years. However, the age composition in the northern areas is still dominated by the strong 1977 year class (6-yr-olds in 1983). This is particularly evident on the east coast of the Queen Charlotte Islands, where 6-yr-olds comprised approximately 75% of the sampled population in 1983. Throughout the north coast and central coast this cohort comprised 45 to 55% of the population.

2.3.2 South

Estimates of spawners and hailed roe catches in 1983 and of total pre-fishery abundance for the period 1974-83 for the southern management units and divisions are shown in Table 2.2. The estimated pre-fishery biomass in the Johnstone Strait division in 1983 was 3,600 tonnes. This is a decrease of 43% from the 1982 estimate and indicates a continuation of the substantial decline since 1980. In the Strait of Georgia division the 1983 pre-fishery biomass estimate of 161,000 t represents a decrease of 30% from the previous year. However, stocks are still higher than the 10-year average.

The 1983 pre-fishery biomass estimate for the west coast of Vancouver Island was 55,400 tonnes. This is an increase of 51% from the previous year but it is still very low in comparison to the 1974-83 average. The estimated abundances in 1983 for West Barkley and Nuchatlitz Inlet are reasonably good with respect to historic levels. However, stocks in all other management units on the west coast of Vancouver Island appear to be in poor shape.

2.4 Forecasts

Forecasts of 1984 runs to management units and to divisions assuming poor, average, and good recruitment are shown in Table 2.3. Because recruitment estimates are based on the assumption that all fish mature and recruit to the spawning population at age 3, recruitment will be underestimated in those areas where a significant proportion of the population does not mature until a later age. This is likely to be an important bias in forecasted runs for northern areas where some fish may not mature until 5 or 6-years old. Spawning requirements were determined in a qualitative way based on historical records of area and substrate utilized, and optimal egg deposition for hatching viable larvae (Hourston 1981). The potential catch is the difference between spawning requirements and the three levels of forecast runs.

These forecasts assume that all spawning stocks are potentially fishable. However, this is not true because of: (1) spawn timing considerations, (2) areas containing primarily resident stocks, and (3) areas which can not be assessed in-season. A more realistic assumption for managers would be that some fraction of the potential catch (say 50-60%) is potentially fishable.

Given average recruitment the potential catch in 1984 is 200 t for the Queen Charlotte Islands, 8,100 t for the north coast, and 15,900 t for the central coast (Table 2.3). Combined, this would be a potential catch of 24,200 t for the northern district. Assuming good recruitment, the potential catch for the entire northern district would be 50,900 t.

The potential catch, assuming average recruitment is 62,600 t for the Strait of Georgia and 3,700 t for the west coast of Vancouver Island (Table 2.3). The forecast runs for the west coast of Vancouver Island given poor recruitment indicate no surplus stocks to support a fishery in 1984. Even under the assumption of average recruitment only 3 of the 7 management units in this division would have runs in excess of spawning requirements.

Table 2.1 Egg correction factors by section used in assessing 1983 spawn deposition.

Section[a]	Survival Factor	Section	Survival Factor
001	0.333	083	0.333
002	0.333	084	0.333
003	0.333	085	0.333*
004	0.333	092	0.333
005	0.333	102	0.333
006	0.333	112	0.333
012	0.333	122	0.333
021	0.333	126	0.333
022	0.333	127	0.333
023	0.333*	132	0.333
024	1.000*	133	0.333
025	0.666	134	0.333
032	0.333	137	0.333
033	0.666*	141	0.333
042	0.666*	142	0.333*
043	0.666*	143	0.333*
051	0.333	144	0.666*
052	1.000*	152	0.666*
053	0.333	172	0.666*
062	0.333	173	0.333*
067	0.333	182	0.666
071	0.333	232	0.333*
072	1.000*	243	0.333*
073	0.333	244	0.333
074	0.333*	245	0.500*
075	0.333*	253	0.333
076	0.333	273	1.000

[a]For section coding see Hourston and Hamer (1979).

*Indicates areas where values were determined in conjunction with diver surveys.

Table 2.2 Catch (tonnes), spawners (tonnes) for 1983, and total abundance (tonnes) for 1974 to 1983 by management unit for Queen Charlotte Island division.

Year	Total QCI Division	Management Unit					
		North Coast 01	Louscoone 02	Other Area 2W 03	Laskeek Bay 04	Skincuttle 05	Other Area 2E 06
			Gillnet Catch				
1983	752	-	-	-	-	752	-
			Seine Catch				
1983	6388	-	-	1738	-	4650	-
			Spawners				
1983	25400	60	1300	12700	1900	7200	2100
			Total Abundance				
1983	32500	60	1300	14400	1900	12600	2100
1982	42100	4400	4700	13100	3200	13000	3700
1981	30300	1400	1300	5700	4700	14000	3000
1980	21600	3600	2100	2800	1600	11500	-
1979	24800	1700	1200	2500	600	13200	5700
1978	36500	5700	2800	1700	-	20000	6200
1977	31500	3200	3400	2400	-	15200	7300
1976	38000	4500	8800	700	700	15200	8000
1975	28900	1900	8500	2000	-	92005	7300
1974	27100	4500	4600	3300	-	6900	7700

Table 2.2 (cont'd) Catch (tonnes), spawners (tonnes) for 1983, and total abundance (tonnes) for 1974 to 1983 by management unit for north coast division.

Year	Total North Coast Division	Management Unit: Chatham Sound 07	Management Unit: Porcher Island 08	Management Unit: Other North Coast 09
			Gillnet Catch	
1983	-	-	-	-
			Seine Catch	
1983	114	-	114	-
			Spawners	
1983	37900	22400	14600	800
			Total Abundance	
1983	38000	22400	14700	800
1982	19500	15600	3400	500
1981	15900	7800	6800	1400
1980	16600	4800	11400	400
1979	39100	29300	9800	-
1978	12100	5000	7000	100
1977	34800	15700	19000	100
1976	55100	38900	16200	-
1975	35600	19200	16300	100
1974	21000	7200	13500	200

Table 2.2 (cont'd) Catch (tonnes), spawners (tonnes) for 1983, and total abundance (tonnes) for 1974 to 1983 by management unit for central division.

Year	Total Central Division	Management Unit							
		Kitasu Bay 10	Milbanke Sound 11	Queens Sound 12	Kwakshua Channel 13	Burke Channel 14	Rivers Inlet 15	Smith Inlet 16	Other Central 17
				Gillnet Catch					
1983	3546	1901	1645	-	-	-	-	-	-
				Seine Catch					
1983	2142	155	1987	-	-	-	-	-	-
				Spawners					
1983	47800	15700	15200	500	3100	800	300	1200	11000
				Total Abundance					
1983	53500	17800	18800	500	3100	800	300	1200	11000
1982	54400	11300	30500	1600	4900	-	1800	3800	600
1981	43900	12200	20200	3100	6800	600	100	500	600
1980	39600	7900	19000	5300	2400	-	300	1600	3000
1979	17500	2000	5900	3500	1900	2600	400	400	800
1978	29300	5100	13600	6300	2000	-	1300	700	200
1977	38800	3100	16900	10100	2400	3300	2500	200	400
1976	37300	4100	15200	6400	3700	4100	1600	400	1800
1975	35100	7500	8600	5000	5300	1900	5000	600	1200
1974	24800	3600	8400	5200	2300	1800	2500	600	500

Table 2.2 (cont'd) Catch (tonnes), spawners (tonnes) for 1983, and total abundance (tonnes) for 1974 to 1983 by management unit for Johnstone Strait division.

Year	Total Johnstone Division	Management Unit: Upper Johnstone 18	Knight Inlet 19	Other Johnstone 20
		Gillnet Catch		
1983	-	-	-	-
		Seine Catch		
1983	-	-	-	-
		Spawners		
1983	3600	300	1400	1900
		Total Abundance		
1983	3600	300	1400	1900
1982	6300	700	4900	800
1981	15600	4100	1100	10400
1980	16100	7600	1600	6900
1979	4200	200	200	3800
1978	3800	2000	1100	700
1977	15000	5700	6600	2700
1976	19800	9700	8700	1400
1975	41200	17600	19300	4300
1974	27500	7600	15600	4300

Table 2.2 (cont'd) Catch (tonnes), spawners (tonnes) for 1983, and total abundance (tonnes) for 1974 to 1983 by management unit for Strait of Georgia division.

Year	Total Strait of Georgia Division	Management Unit						
		Powell River 21	Nanaimo Comox 22	Yellow Point 23	Ganges Plumper 24	Area 29 25	Other Mainland 26	Gulf Island 27
				Gillnet Catch				
1983	8574	-	8574	-	-	-	-	-
				Seine Catch				
1983	8369	3891	4478	-	-	-	-	-
				Spawners				
1983	144000	6400	70900	50300	100	-	-	16300
				Total Abundance				
1983	161000	10300	83900	50300	100	-	-	16300
1982	231600	15700	162500	37200	600	-	400	15200
1981	127000	13000	92000	19500	2000	-	-	400
1980	74300	5300	57700	7800	800	600	1200	800
1979	128400	44400	73000	9600	700	-	-	800
1978	116300	20400	82300	9700	1600	100	-	2200
1977	107900	33400	60300	10900	1300	1000	300	800
1976	121100	20100	81000	13700	1800	2800	500	1200
1975	98100	14000	46900	6600	22200	5500	500	2400
1974	140300	7700	73100	35700	20900	2300	500	100

Table 2.2 (cont'd) Catch (tonnes), spawners (tonnes) for 1983, and total abundance (tonnes) for 1974 to 1983 by management unit for West Coast of Vancouver Island division.

Year	Total WCVI Division	Management Unit							
		West Barkley 28	Other Area 23 29	South Clayquot 30	Other Area 24 31	Nootka Sound 32	Nuchatlitz Inlet 33	Quatsino Sound 34	Other Upper West Coast 35
					Gillnet Catch				
1983	2600	-	-	-	-	-	2432	168	-
					Seine Catch				
1983	6178	6178	-	-	-	-	-	-	-
					Spawners				
1983	46700	23300	-	2300	800	-	11300	9000	-
					Total Abundance				
1983	55400	29500	-	2300	800	-	13700	9200	-
1982	36700	9100	-	3700	500	6400	11400	5600	-
1981	64500	14000	-	25800	1800	5000	10600	7400	-
1980	88100	9100	-	30300	3000	-	13600	32100	-
1979	113600	15700	200	21200	3200	42500	14400	16400	-
1978	93100	13100	1500	38200	4900	700	21900	12600	200
1977	106700	35100	1900	44200	4300	800	19000	900	400
1976	127400	29100	14700	54300	16100	2300	9600	500	900
1975	128100	18200	1200	46300	17300	14000	23400	6400	1400
1974	92900	25100	-	40000	2100	21000	2900	500	1400

Table 2.3 Forecast of the 1984 runs and potential catch in tonnes (x 1000) of fish by management unit for good, average, and poor recruitment.

Division and Management Unit	Adults	Recruits			Run			Spawners	Potential Catch		
		Poor	Average	Good	Poor	Average	Good	Required	Poor	Average	Good
Queen Charlotte Is.											
North Coast	<.1	0.1	1.0	2.4	0.2	1.0	2.4	2.0	-	-	0.4
Louscoone Inlet	0.7	<.1	0.5	1.3	0.7	1.2	2.0	3.0	-	-	0.0
Other Area 2W	7.1	0.1	0.5	1.2	7.2	7.6	8.3	2.0	5.2	5.6	6.3
Laskeek Bay	1.1	<.1	0.2	0.8	1.1	1.3	1.9	4.0	-	-	0.0
Skincuttle Inlet	4.2	0.2	2.0	4.9	4.4	6.2	9.1	7.0	-	-	2.1
Other Area 2E	1.2	0.4	1.2	2.2	1.6	2.4	3.4	1.5	0.1	0.9	1.9
All	14.3	0.8	5.4	12.6	15.1	19.7	27.0	19.5	-	0.2	7.5
North Coast											
Chatham Sound	13.8	<.1	1.8	4.7	13.8	15.6	18.5	10.0	3.8	5.6	8.5
Porcher Island	10.6	0.1	2.2	6.9	10.7	12.8	17.5	10.0	0.7	2.8	7.5
Other North Coast	0.6	<.1	0.1	0.3	0.6	0.7	0.9	1.0	-	-	-
All	25.0	0.2	4.1	11.9	25.2	29.1	37.0	21.0	4.2	8.1	16.0
Central											
Kitasu Bay	9.6	<.1	1.1	3.6	9.6	10.7	13.2	4.0	5.6	6.7	9.2
Milbanke Sound	9.1	0.4	2.1	5.8	9.5	11.2	14.9	8.0	1.5	3.2	6.9
Queens Sound	0.3	0.1	0.9	2.2	0.3	1.2	2.4	3.0	-	-	-
Kwakshua Channel	2.0	<.1	0.9	2.3	2.1	2.9	4.4	2.0	0.1	0.9	2.4
Burke Channel	0.4	0.1	0.4	0.6	0.6	0.8	1.1	2.0	-	-	-
Rivers Inlet	0.2	<.1	0.5	1.5	0.2	0.7	1.7	1.5	-	-	0.2
Smith Inlet	0.8	<.1	0.2	0.7	0.8	1.0	1.5	0.5	0.3	0.5	1.0
Other Central	8.4	<.1	0.5	1.4	8.4	8.8	9.8	0.4	8.0	8.4	9.4
All	30.8	0.7	6.5	18.0	31.5	37.3	48.8	21.4	10.1	15.9	27.4

Table 2.3 (cont'd) Forecast of the 1984 runs and potential catch in tonnes (x1000) of fish by management unit for good, average, and poor recruitment.

Division and Management Unit	Adults	Recruits			Run			Spawners	Potential Catch		
		Poor	Average	Good	Poor	Average	Good	Required	Poor	Average	Good
Johnstone Strait											
Upper Johnstone Str.	0.2	<.1	1.4	4.0	0.2	1.6	4.2	4.0	-	-	0.2
Knight Inlet	1.0	<.1	0.7	2.0	1.0	1.7	3.0	2.0	-	-	1.0
Other Johnstone Str.	1.4	0.2	1.5	3.8	1.5	2.8	5.1	4.0	-	-	1.1
All	2.6	0.2	3.6	9.8	2.8	6.2	12.3	10.0	-	-	2.3
Gulf of Georgia											
Powell River	4.3	1.1	4.3	8.5	5.4	8.5	12.8	10.0	-	-	2.8
Nanaimo-Comox	43.6	3.4	19.4	39.6	47.0	63.0	83.3	40.0	7.0	23.0	43.3
Yellow Point	32.5	0.5	6.4	17.7	33.0	38.9	50.3	10.0	23.0	28.9	40.3
Ganges-Plumper	<.1	<.1	3.1	11.1	0.1	3.1	11.1	4.0	-	-	7.1
Other Gulf Van. Is.	12.8	<.1	1.0	3.3	12.8	13.8	16.1	0.8	12.0	13.0	15.3
All	93.3	5.1	34.2	80.3	98.3	127.4	173.6	64.8	33.5	62.6	108.8
West Coast of Van. Is.											
West Barkley	13.5	0.7	4.0	8.4	14.2	17.5	22.0	10.0	4.2	7.5	12.0
South Clayoquot	1.5	0.2	5.6	13.9	1.7	7.1	15.4	15.0	-	-	0.4
Other Area 24	0.5	0.1	1.1	2.8	0.6	1.6	3.3	2.0	-	-	1.3
Nuchatlitz Inlet	6.6	0.5	3.6	9.8	7.2	10.2	16.5	10.0	-	0.2	6.5
Quatsino Sound	6.6	<.1	3.6	12.9	6.6	10.2	19.5	6.0	0.6	4.2	13.5
All	28.8	1.6	17.9	47.8	30.4	46.7	76.6	43.0	-	3.7	33.6

3. AGE-STRUCTURED MODEL

3.1 Introduction

The use of models utilizing age structure data for stock reconstruction is well documented in fisheries literature. Simple models use only age structure data (eg. cohort analysis); more complex methods incorporate additional information about the stocks (e.g. cpue data). The age-structured model used to assess B.C. herring stocks since 1982 (Stocker et al. 1983) is a modification of the model described in Fournier and Archibald (1982). The basic model includes realistic assumptions about the form of both measurement and process errors. A maximum likelihood method is used to simultaneously estimate all model parameters (e.g. natural and fishing mortality rates, stock-recruitment parameters). The flexibility of this model to incorporate additional information about the populations has been used to include the spawn survey data available for B.C. herring.

Three structural assumptions are made to include the spawn data in the age-structured model. One is the form of the relationship between the true spawn and the observed spawn, the second is the form of the relationship between escapement and true spawn, and the third is the existence of a spawn-recruitment relationship. Two additional structural assumptions inherent in this model are the form of the catch equations and the form of equations describing natural and fishing mortalities.

Statistical assumptions which are included in the estimation procedure include the form of error in the catch estimates and in the estimates of the age structure. Assumptions are also made regarding the form of errors in the spawn relationships.

3.2 Methods

The general age-structured model used in this analysis has been described in detail elsewhere (Fournier and Archibald 1982); the inclusion of spawn data in the model is also documented (Stocker et al. 1984). Only a cursory description of the model is included here.

Parameters which are estimated by the model include the instantaneous rates of fishing (F) and natural (M) mortalities as well as the numbers of fish in year i at age j (N_{ij}) for each year of the data series. The estimates are determined by minimizing an objective function which has terms for all components of the model. Simplified versions (variance estimates and constants are not included) of the major components of the objective function are:

- the log likelihood function for the parameters P_{ij} and C_i

$$\sum_{ij} S_{ij} \log P_{ij} - w \sum_{i} (\log O_i - \log C_i)^2$$

- the contribution from the true spawn - recruitment relationship (a Ricker type parameterization is used)

$$- w\sum_i (\log (N_{i+1,1}) - \log\alpha - \log (TS_i) + \beta TS_i)^2$$

- the contribution from the true spawn-escapement relationship

$$-w\sum_i (\log (\sum_i f_j N_{ij}) - QSP - \log (TS_i))^2$$

- the contribution from the true spawn - observed spawn relationship

$$- w\sum_i (\log(TS_i) - CSP - \log(OS_i))^2$$

where S_{ij} = the number of fish observed to be of age j in year i

P_{ij} = the actual percentage of fish of age j in the catch in year i

O_i = estimated number of fish caught in year i

C_i = actual number of fish caught in year i

f_j = relative fecundity of fish of age j

TS_i = true spawn in year i

QSP = true spawn - escapement coefficient

OS_i = observed spawn in year i

The penalty weights (w) are assigned by the user and reflect his intuition about the relative accuracy of the data. The spawn related penalty weights used in all runs in this analysis are :

20 for the true spawn - escapement relationship

10 for the true spawn - observed spawn relationship

5 for the true spawn - recruitment relationship

These penalty weights reflect our belief that herring do not follow a very strong stock - recruitment relationship , and our mistrust of the earlier spawn index data. By placing the highest weight on the true spawn-escapement relationship the true spawn estimates will follow the escapement estimates from the age structure data to a relatively greater degree.

To evaluate the potential effect time trends in the spawn index may have on estimates of current stock size, we ran a second set of computer runs, for all stock groupings. Observed irregularities in the spawn data determined three blocks of years within which consistency in spawn measurements were assumed: 1951-68, 1969-75, 1976-83. The true spawn-observed spawn coefficient (CSP) was set at 1 for the first block of years but was allowed to vary for the other two (CSP becomes CSP_k where k is the block of time).

Instantaneous fishing (F_{ij}) and natural (M_{ij}) mortality rates are incorporated in the model through the catch equations :

$$P_{ij}C_i = F_{ij}/(F_{ij} + M_{ij})\ (\ 1 - \exp(-F_{ij}-M_j))\ N_{ij}$$

The instantaneous fishing mortality rates are defined as described in Fournier and Archibald (1982). Basically, this involves parameters for the average fishing level each year and parameters for age specific selectivity. In this analysis two age specific vulnerability curves are used to account for different selectivities between the reduction and the roe fisheries. The model is set up to allow various forms of instantaneous natural mortality. These include constant natural mortality for all years and ages and density dependent natural mortality (Fournier 1983) where the instantaneous rate is a linear function of the estimated yearly biomass. In previous analyses (e.g. Stocker et al. 1983) annual biomass was calculated over all ages and the estimated biomass dependent natural mortality applied to all age groups. However, this is not the most reasonable assumption to make for B.C. herring stocks because pre-recruit fish school separately from adults and will be subject to different mortality pressures. Also, few immature fish are caught in the fishery so there is little information to determine cohort size prior to maturation. For the current stock assessment density dependent natural mortality is applied only to age 3 and older fish and is dependent on the estimated biomass of age 3+ fish. In all analyses to date natural mortality rates were not well determined, and in most cases unrealistically high values were estimated. For this reason the rate for the first set of computer runs was set at 0.45, a value similiar to other estimates (e.g. Tester 1955). In the second set of computer runs the natural mortality rate was assumed to be density dependent.

Forecast of spawning stocks for 1984 were calculated by assuming all natural mortality will occur prior to spawning and therefore prior to the roe fishery. The numbers of fish at age prior to the fishery are therefore the numbers estimated at the beginning of the 1983/84 season minus the number dying through the year. Biomass estimates were calculated by applying average weights at age to the estimated numbers at age.

3.3 Status of Stocks

3.3.1 North

Pertinent parameter estimates and the objective function values for the northern stock groupings are shown in Table 3.1. The results labelled "constant" are those produced from the assumptions of constant natural mortality and spawn index. Those labelled "variable" are the result of the assumptions of density dependent natural mortality and a time dependent spawn index.

Two assumptions used in northern stock assessments in previous analyses have been changed for these runs. These are: (1) density dependent natural mortality is estimated only for age 3 and older fish, as already discussed, and (2) maturation ogives are time independent. Previously estimates of proportion of fish mature at age for the northern areas were estimated from annual winter catch samples. However, these samples are likely to be biased towards mature fish; results had indicated that most fish age 3 and older, and even significant proportions of age 2 fish, were mature. For

this analysis, we assume 60% of the age 3 and all older fish are mature. This assumption is used to estimate the relative fecundity (f_j) of age classes and therefore the annual reproductive potential of the population.

These changes in model assumptions have produced some qualitatively different stock reconstructions, particularly for the north coast. In previous analyses, the reconstruction under the variable assumptions indicated the north coast stock did not recover appreciably since the reduction crash (see Stocker et al. 1983), whereas, the current analysis indicates virtually no difference in the stock trends between the constant and variable assumptions.

For all northern "stocks" there is a reasonable improvement in model fit, as measured by the objective function value, when the additional assumptions of the "variable" runs are incorporated into the model. In all cases density dependent natural mortality followed an inverse trend, that is, higher natural mortality rates were estimated for lower biomass estimates. The spawn index conversion factors are all less than one, with the exception of the estimate for the north coast for the period 1969-75. This supports our assumption that there is a temporal trend in the spawn index. However, there is no simple statistic to evaluate the relative validity of the assumptions in the "constant" and "variable" models.

The estimated numbers of age 3 and older fish for the period 1950-83 for the three northern areas and the combined north under both sets of assumptions are shown in Fig. 3.1. The numbers are estimates for the beginning of the season (July 1) so they will be somewhat higher than pre-fishery stock abundances for the roe fisheries. The number of 3+ fish estimated for the Queen Charlotte Islands in 1983 for both the "constant" and "variable" assumptions is 1,000 million. This represents an average decrease of 17% from the 1982 estimates. The 1983 abundance estimates for the north coast under the two sets of assumptions are 1,150 and 1,160 million fish. This is an average decrease of 18% from the 1982 estimates. The estimated numbers of age 3+ fish in 1983 in the central coast are 680 and 480 million under the "constant" and "variable" assumptions respectively. This is an average 16% decrease from the 1982 estimates. Both scenarios indicate a steady decline in numbers since the relatively high estimates for 1974. The estimated numbers of age 3+ fish in 1983 for the combined northern stocks are 1,980 and 1,910 million for the two sets of assumptions. This is an average decrease of 16% from the 1982 estimates. Current stock estimates are considerably lower than the historic average.

All three northern areas indicate considerable stock declines since the 1979/80 season. The spawn index for all areas has remained relatively constant over the past 4 years and in the central and north coast the index is higher in 1983 than in the previous 3 years. This indicates an inconsistency between the spawn index and age structure data. Since 1980, these stocks have been dominated by a large 1977 year class (6 yr-olds in 1983). One explanation, which would be consistent with the age structure and spawn data is that considerable proportions of this cohort did not mature until ages 4, 5, and even 6. Alternatively, there may be large groups of younger fish (age 3 and 4) which spawn later in the season, and therefore are not sampled by the roe fisheries.

The analysis of the central coast is likely to be biased because of abrupt changes in the type of fishery and gear selectivity during the years when the 1977 cohort was first recruiting. During the 1978/79 season the only central coast fishery was a winter seine fishery. In 1979/80 the fishery was strictly a gillnet roe fishery. Since then, there have been both gillnet and seine roe fisheries. The gillnet catch samples for the 1979/80 season did not indicate the strong 1977 year class which showed up in the pre-fishery charter samples (65-70% 3-yr-olds). The result is that the model estimates this cohort to be only average size.

3.3.2 South

Model parameter estimates and the objective function values for the southern stock groupings for both sets of runs are shown in Table 3.2. As in the northern areas the "variable" runs assume density dependent natural mortality and time dependent spawn index. Stock reconstructions for the period 1950-83 under both sets of assumptions are shown in Fig. 3.2.

The estimates of the spawn index conversion factors for the Strait of Georgia are greater than one, for both time periods, and are greater than one for the combined southern area in the second time period. This is contrary to our belief that more recent spawn measurements overestimate spawn relative to the earlier years. However, the stock reconstructions for the Strait of Georgia, are not qualitatively different between the constant and variable assumptions. For the west coast of Vancouver Island, and the combined southern area the results are different only in the magnitude of the stock recovery after the crash in the late sixties.

As in the northern areas, density dependent natural mortality followed an inverse, or depensatory, relationship with estimated biomass. This trend was not very strong in the Strait of Georgia stock, and the decrease in objective function value under the "variable" assumptions was minimal for this area. However, the depensatory trend in natural mortality is consistent for all stock analyses, indicating this may be a significant factor in the stock dynamics.

The numbers of fish estimated for the Strait of Georgia and Johnstone Strait in 1983 under the "constant" and "variable" assumptions are 1,530 and 1,700 million respectively. These numbers represent a decrease of 3% from the 1982 estimates. The 1983 estimates for the west coast of Vancouver Island are 870 and 600 million age 3+ fish under the two scenarios. This represents an average increase of 26% from the 1982 estimates. The stock reconstructions indicate a steady decline in numbers since 1974, with current estimates lower than the historic average. The numbers of fish estimated for the entire southern area in 1983 are 2,300 and 2,000 million. These stock levels are slightly lower than the historic average.

3.4 Forecasts

Forecasts of numbers and tonnes of age 4+ fish prior to the 1984 spawning season and of the potential catch (tonnes) in 1984 are shown in Table 3.3 for all stock groupings. The potential catch in tonnes is calculated as 20% of the predicted pre-spawning age 4+ biomass. Because stock estimates

from this method are for the entire population rather than the spawning component we have not included 3 year old fish in the forecasted runs. Although significant proportions of 3-yr olds spawn, particularly in the southern areas, the exact proportion is not known. For the northern areas there are strong indications that some fish do not mature until much later (age 5 and 6). Also, the forecast of 3-yr olds is not well determined because there is little information about relative recruitment prior to their catch in the fisheries. The predicted millions of fish, age 3 and older, are shown in Table 3.4. For the southern areas, the forecasts indicate 3-yr old fish will comprise a significant proportion of the population (43-56%). Therefore using only the 4+ biomass to calculate potential catch may significantly underestimate available catch for these areas.

The potential catch predictions for 1984 do not vary greatly between the assumptions of a constant spawn index and natural mortality , and a variable spawn index and density dependent natural mortality for all stock groupings except the west coast of Vancouver Island. The average potential catch estimate for the north coast is 15,500 t. The average predictions for the Queen Charlotte Islands and the central coast are 14,000 t and 6,700 t respectively. The average potential catch predicted for the entire northern area is 25,700 t. The two estimates of potential catch for the west coast of Vancouver Island are 6,700 t and 3,700 t. The average prediction for the Strait of Georgia and Johnstone Strait is 18,500 t. The prediction for the entire southern area is a potential catch of 23,100 t.

Table 3.1 Model parameter estimates and objective function values for the northern stock groupings.

Area	Objective Function Value	Instantaneous Natural Mortality rate	True Spawn-Escapement Coefficient (QSP)	Spawn Index conversion factor (CSP_k) 1969-75	1976-83
Queen Charlotte Islands-constant[a]	592	0.45	0.11		
-variable[b]	525	0.22-0.82	0.064	0.54	0.38
North Coast-constant	610	0.45	0.085		
-variable	592	0.37-0.52	0.097	1.84	0.85
Central Coast-constant	536	0.45	0.32		
-variable	509	0.25-0.77	0.29	0.55	0.93
Combined North-constant	365	0.45	0.22		
-variable	350	0.30-0.66	0.19	0.68	0.67

[a]"constant" assumes constant natural mortality and spawn index.

[b]"variable" assumes density dependent natural mortality and time dependent spawn index.

Table 3.2. Model parameter estimates and objective function values for the southern stock groupings.

Area		Objective Function Value	Instantaneous Natural Mortality Rate	True Spawn-Escapement Coefficient (QSP)	Spawn Index conversion factor (CSP_k) 1969-75	1976-83
Strait of Georgia and Johnstone Strait	-constant[a]	395	0.45	0.34		
	-variable[b]	390	0.41-0.50	0.39	1.27	1.57
West Coast of Vancouver Island	-constant	392	0.45	0.20		
	-variable	357	0.11-0.95	0.23	0.87	0.96
Combined Southern Area	-constant	302	0.45	0.29		
	-variable	285	0.27-0.94	0.39	0.87	1.40

[a]"constant" assumes constant natural mortality and spawn index.

[b]"variable" assumes density dependent natural mortality and time dependent spawn index.

Table 3.3. Forecast of the 1984 runs and potential catch.

Area	Millions of Age 4+ fish prior to 1984 spawning	Tonnes (x1000) of Age 4+ fish prior to 1984 spawning	Potential catch in tonnes (x1000)
Queen Charlotte Islands			
-constant[a]	459	69.2	13.8
-variable[b]	476	72.6	14.5
North Coast			
-constant	609	82.0	16.4
-variable	551	73.1	14.6
Central Coast			
-constant	267	39.7	7.9
-variable	186	27.9	5.6
Total North			
-constant	900	133.5	26.7
-variable	833	123.4	24.7
West Coast of Vancouver Island			
-constant	246	33.6	6.7
-variable	132	18.3	3.7
Strait of Georgia/Johnstone Strait			
-constant	558	84.2	16.8
-variable	664	100.4	20.1
Total South			
-constant	851	114.9	23.0
-variable	849	115.8	23.2

a"constant" assumes constant natural mortality and spawn index.

b"variable" assumes density dependent natural mortality and time dependent spawn index.

Table 3.4. Predicted millions of age 3 and older fish in 1984.

Area	Age								Total
	3	4	5	6	7	8	9	10	
Queen Charlotte Islands									
-constant[a]	180	29	154	16	223	8	19	10	639
-variable[b]	176	25	136	16	254	10	22	13	652
North Coast									
-constant	121	254	132	70	132	9	4	8	730
-variable	195	253	111	58	110	8	4	7	746
Central Coast									
-constant	166	48	54	32	81	6	36	10	433
-variable	85	26	36	21	62	4	28	9	271
Total North									
-constant	361	102	271	69	388	23	28	19	1261
-variable	345	94	247	64	362	22	26	18	1178
Strait of Georgia/Johnstone Strait									
-constant	417	192	169	79	55	21	25	17	975
-variable	428	216	199	96	69	27	34	23	1092
West Coast Vancouver Island									
-constant	309	102	54	34	28	8	17	3	555
-variable	189	51	28	18	17	5	11	2	321
Total South									
-constant	640	308	236	132	88	29	41	17	1491
-variable	486	276	234	138	96	33	50	22	1335

[a]"constant" assumes constant natural mortality and spawn index.

[b]"variable" assumes density dependent natural mortality and time dependent spawn index.

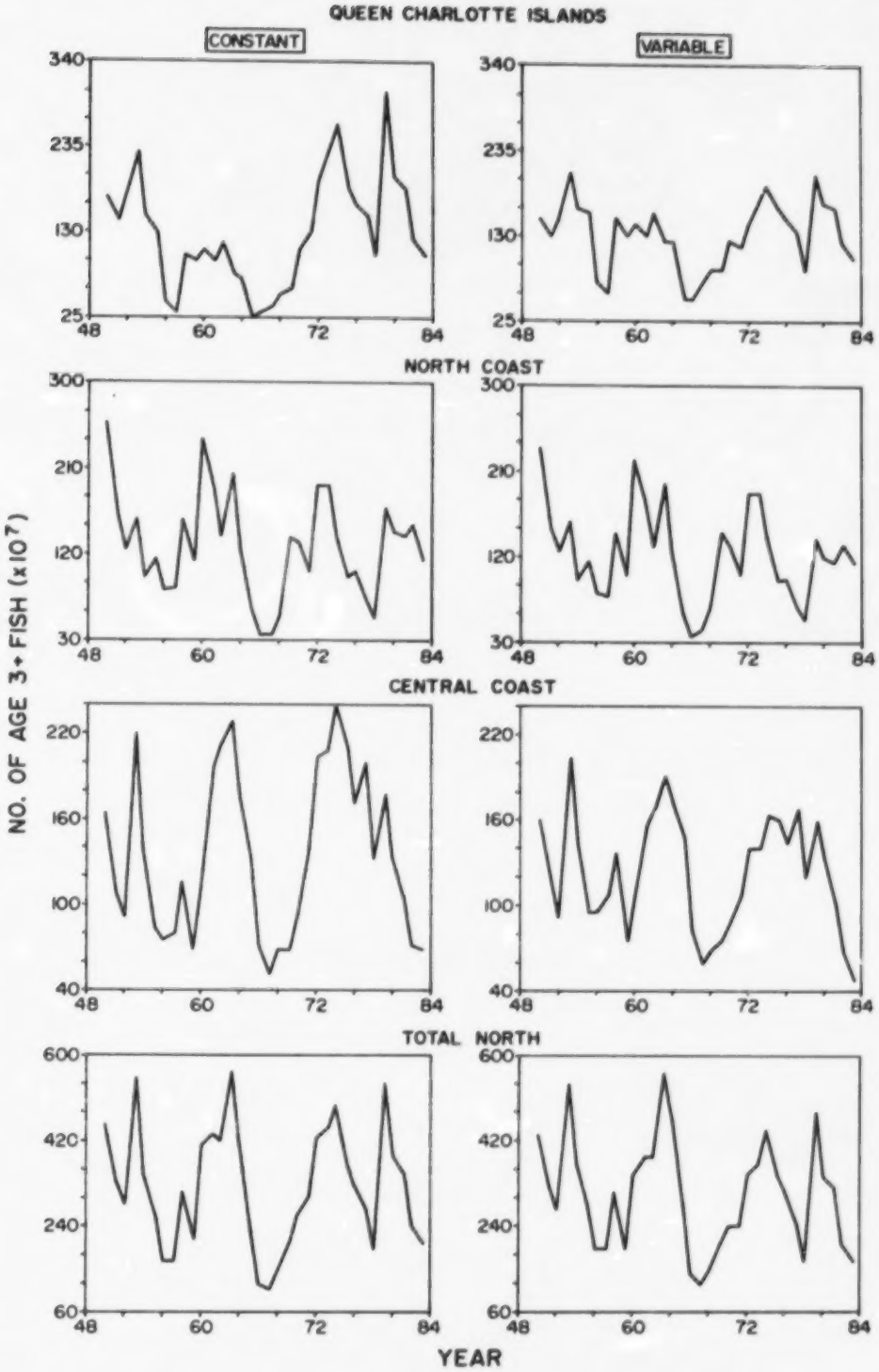

Fig. 3.1. Estimates numbers of age-3 and older northern herring, 1951-1983.

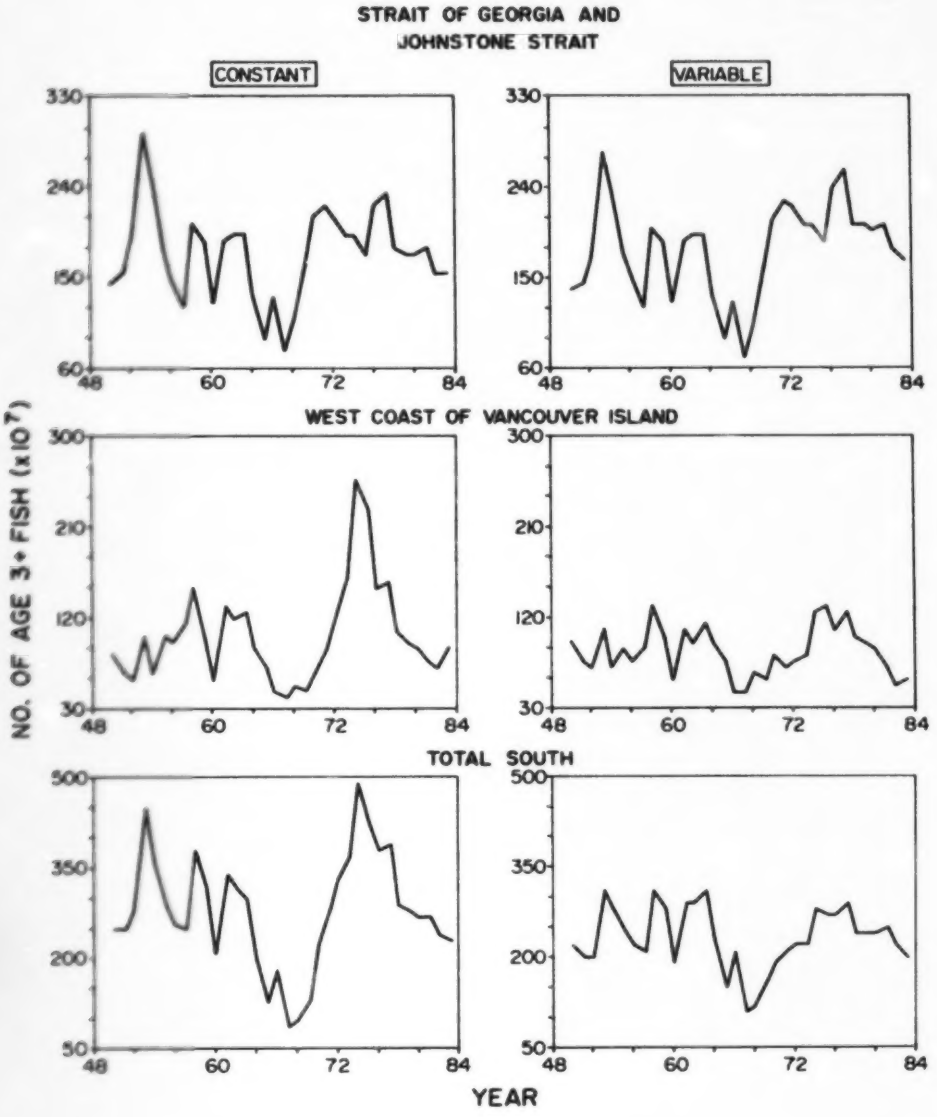

Fig. 3.2. Estimated numbers of age-3 and older southern herring, 1951-1983.

4. SURPLUS PRODUCTION MODEL ANALYSIS

4.1 Introduction

In surplus production models changes in productivity are expressed in quantitative relationships. Based on productivity estimates, catch estimates are predicted for stocks. We assume that the proportion of the stock dying each year increases with stock size and also that the number of births increase as stock size increases. The difference between births and deaths at any stock size is the source of surplus production to be harvested.

4.2 Methods

A measure of herring abundance of the different stocks based on a Spawn Index (S) was used for these analyses. The following relationship between catch and escapement for the years 1951-83 was examined to assess stock sizes and productivity:

$$(4.1) \qquad E_t + C_t = E_{t-1} + rE_{t-1}\left(1 - \frac{E_{t-1}}{k}\right)$$

where E_t = escapement biomass in year t
C_t = catch in year t
r = growth parameter
k = unfished equilibrium population size.

If we specify E_t as:

$$(4.2) \qquad E_t = \frac{S_t}{q}$$

where S_t = Spawn Index in year t
q = proportionality constant,

then equations 4.1 and 4.2 can be transformed into a linear regression of the form:

$$(4.3) \qquad \left[\frac{S_t}{S_{t-1}} - 1\right] = r - \frac{r}{qk} S_{t-1} - q\frac{C_t}{S_{t-1}}$$

Given a time series of C_t's and S_t's, the best estimates of the three model parameters r, k, and q can be obtained by multiple regression. This version of the surplus production model is referred to as "constant". It is assumed that q is "constant" over time (i.e. no time trends in the spawn index).

To evaluate the potential effect time trends in the spawn index may have on biomass estimates a second version ("variable") of the model assumes variable q. We specify E_t as:

$$E_t = q \frac{S_t}{P_t}$$

where P_t = year specific spawn coefficient. Observed irregularities in the spawn data determined three blocks of years within which constant spawn measurements were assumed: 1951-68, 1969-75, and 1976-82 (Stocker et al. 1982: 22). P_t is set at 1 for the first block of years, and set at $1/CSP_k$ for the other two blocks of years. Parameter values for CSP_k were estimates using age-structured model analysis (Stocker et al. 1983; Tables 3.1, 3.2).

The production of the population, which is the second term on the right-hand side of equation 4.1, is the difference between pre-fishery biomass in a given year ($E_t + C_t$) and the escapement the previous year (E_{t-1}). For data sets that produced poor model fits average production from 1951-83 was used for forecasting 1984 stock sizes ($\hat{B}_{84}$)

$$\hat{B}_{84} = \frac{1}{q} S_{83} + \text{average production} \pm 1S.D.$$

For those data sets which produced singificant model fits the average 1984 stock sizes ($\hat{B}_{84}$) were forecast as:

$$(4.4) \qquad \hat{B}_{84} = \frac{1}{q} S_{83} + \frac{r}{q} S_{83} - \frac{r}{kq^2} S_{83}^2.$$

Low and nigh runs were forecast, using standard deviations of the coefficients (r, k, q).

A simple procedure was used to calculate recommended catch quotas. The catch quotas are established at 20% of the forecast 1984 stock sizes.

4.3 Status of stocks

4.3.1 North

Spawn indices (S) and catch (tonnes) for the years 1951-83 are summarized in Table 4.1 for the three northern Divisions as well as the entire North. Predicted and observed pre-fishery abundance for the years 1951-82 in relation to proportionality constant q are shown in Fig. 4.1 for the northern stock groupings. The 1983 pre-fishery biomass for the Queen Charlotte Islands

was estimated at 132,000 t and 77,000 t for constant and viariable q respectively. This represents an 11% decrease of the 1982 pre-fishery biomass. For the north coast the estimates are 60,000 t and 27,000 t for the two q assumptions, which is up by 33% from 1982. The central coast pre-fishery biomass for 1983 was estimated as 220,000 t and 180,000 t for the two cases indicating an increase of 25% from the previous year. For the entire north the abundance of the 1983 pre-fishery biomass was estimated as 405,000 t and 354,000 t for the constant and variable assumptions, respectively. This presents an increase from the previous year of 15%. Generally, in the north there has been an increase in pre-fishery biomass since 1978 which is probably mainly attributable to the strong 1977 year-class.

4.3.2 South

Spawn indices (S) and catch (tonnes) for the period 1951-83 are summarized in Table 4.2 for the two southern groups as well as the entire south.

Production for the southern stock groupings from spawning stocks for the period 1951-83 is shown in Fig. 4.2. Production is for the two cases where q is assumed to be constant or variable over time. Great variability in production has occurred over the time period considered. Similar variability in production is observed from the separate stock groupings for Queen Charlottes, north coast, and central coast. As pointed out, for forecasting 1984 pre-fishery biomass the average production with the appropriate standard deviations or equation 4.3 were used.

Observed and predicted pre-fishery abundances for the period 1951-83 in relation to proportionality constant q are shown in Fig. 4.3 for the southern stock groupings. The 1983 pre-fishery biomass for the west coast of Vancouver Island was estimated as 72,000 t and 105,000 t for constant and variable q, respectively. This represents a decline of 14% since 1982. For the Gulf of Georgia and Johnstone Strait the estimates are 193,000 t and 186,000 t for the two q assumptions, which is down by 15% from the 1982 pre-fishery biomass. For the entire South the abundance of the 1983 pre-fishery biomass was estimated as 299,000 t and 431,000 t for the two proportionality constant assumptions, respectively. This presents a decrease of 15% over the previous year. Generally, in the South there has been a decline since 1980 indicating a lack of strong production of recruits in recent years.

4.4 Forecast

Forecasts of the 1984 runs and potential catch of herring for low, average, and high production are summarized in Tables 4.3 and 4.4 for the north and south respectively.

Assuming average production and a variable proportionality constant q, a run of 390,000 t is forecast for the northern district (Table 4.3). Based on a 20% exploitation rate, the average potential catch would be 78,000 t, with a range of 64,000 t to 92,000 t depending on the production assumption of low and high respectively.

A run of 85,000 t is forecast for the Queen Charlotte Islands, assuming average production and variable q. This would provide a quota of 17,000 t for that district. Abundance is forecast to remain relatively low in 1983 for the north coast district. A run of 38,000 t with a potential quota of 8,000 t is predicted for an average production year. The 197,000 t run forecast for the central coast district, assuming variable q and average production, would leave a potential quota of 39,000 t.

Assuming average production and constant q, a run of 366,000 t is forecast for the southern district. The latter assumption is based on more consistent spawn observations over time in the southern district. Based on the 20% recommended exploitation rate the average potential catch would amount to 73,000 t, ranging from 54,000 t to 93,000 t depending on the production being low or high respectively.

Abundance is forecast to remain relatively low in the west coast of Vancouver Island district in 1984. A run of 81,000 t with a potential quota of 16,000 t is predicted for an average production year and constant q. The surplus production analysis predicts a run of 233,000 t for the Strait of Georgia and Johnstone Strait district in 1984. This would provide a quota of 46,000 t for an average production year.

Table 4.1. Spawn index (S) and catch (x1000 tonnes) by Division for the North, 1951-1983.

	Divison							
	QCI		North Coast		Central		Total North	
Year	S	Catch	S	Catch	S	Catch	S	Catch
1951	70	2.8	226	45.9	402	45.2	698	93.9
1952	49	10.3	127	52.4	212	36.4	388	99.1
1953	121	0.0	186	1.9	454	0.8	760	2.6
1954	192	26.0	145	27.3	379	29.5	716	82.8
1955	99	20.3	198	17.8	386	31.6	683	69.7
1956	86	83.7	165	10.2	273	45.0	524	138.8
1957	25	25.2	287	28.0	144	39.5	456	92.7
1958	18	11.4	109	4.5	232	12.8	359	28.7
1959	223	17.6	193	10.2	254	35.8	670	63.6
1960	141	3.1	171	18.5	461	10.8	774	32.4
1961	201	2.6	148	42.7	256	38.6	605	83.9
1962	142	14.7	263	27.7	486	36.6	890	79.0
1963	114	17.6	106	40.2	222	59.0	442	116.9
1964	122	32.1	184	30.3	316	50.4	622	112.8
1965	40	42.4	59	44.2	233	26.1	332	112.7
1966	49	6.5	37	17.3	121	56.3	207	80.1
1967	24	0.8	26	8.0	328	33.5	378	42.2
1968	24	0.2	57	2.1	238	3.6	318	5.9
1969	61	0.2	11	0.5	124	0.1	195	0.8
1970	105	0.0	149	1.5	672	0.2	926	1.7
1971	212	0.4	124	3.5	722	4.1	1058	8.0
1972	243	4.2	132	4.5	664	11.2	1038	19.8
1973	235	8.6	118	1.6	992	10.2	1344	20.4
1974	316	7.2	96	3.8	774	10.1	1186	21.1
1975	263	8.2	105	1.7	766	9.9	1134	19.7
1976	403	14.4	171	4.3	1054	13.1	1628	31.8
1977	396	12.9	129	8.1	864	11.1	1389	32.2
1978	351	12.5	77	8.6	393	14.1	821	35.2
1979	319	9.1	153	4.3	571	0.0	1042	13.4
1980	566	3.4	218	3.4	645	0.5	1429	7.4
1981	523	6.9	211	3.1	684	3.0	1418	13.0
1982	593	5.7	176	2.0	628	6.6	1397	14.2
1983	517	7.3	249	0.1	854	5.7	1620	13.1

Table 4.2. Spawn index (S) and catch (x 1000 tonnes) by Divison for the South, 1951-1983.

	West coast Vancouver Island		Strait of Georgia & Johnstone Strait		Total South	
Year	S	Catch	S	Catch	S	Catch
1951	226	22.0	554	47.4	780	69.4
1952	128	27.0	676	53.5	804	80.5
1953	373	0.0	1474	8.4	1847	8.4
1954	231	37.6	946	71.5	1177	111.0
1955	248	12.6	889	70.5	1137	83.3
1956	309	17.6	491	73.6	800	91.3
1957	376	3.1	352	72.5	727	78.3
1958	242	0.6	486	23.5	727	34.5
1959	152	69.8	596	55.6	748	125.9
1960	132	55.8	684	76.6	815	132.4
1961	202	30.8	558	51.8	760	82.7
1962	351	28.4	423	75.6	774	119.9
1963	162	21.2	603	79.2	764	122.6
1964	534	22.1	588	89.7	1121	124.7
1965	236	18.8	372	65.2	609	103.5
1966	84	12.4	296	53.6	380	83.5
1967	87	15.4	253	45.9	340	75.6
1968	97	0.0	341	5.3	439	7.0
1969	145	0.0	603	0.8	748	0.8
1970	345	0.0	1041	0.9	1386	0.9
1971	311	0.0	882	1.8	1193	1.8
1972	329	0.0	797	13.1	1126	20.0
1973	224	18.3	662	17.0	886	35.3
1974	181	16.9	1017	6.3	1198	23.2
1975	354	26.1	1189	7.6	1544	33.7
1976	364	39.0	841	13.8	1205	52.8
1977	341	30.1	820	18.3	1161	48.5
1978	327	22.9	767	24.8	1094	47.7
1979	493	19.4	865	20.5	1358	39.9
1980	574	4.5	994	5.9	1569	10.4
1981	371	8.7	635	12.2	1006	21.0
1982	244	6.1	799	12.9	1043	18.9
1983	203	8.8	669	18.3	872	27.0

Table 4.3. Forecast of the 1984 runs and potential catch in tonnes (x1000) of fish for the North for low, average, and high production in relation to proportionality constant q.

Division		Spawners 1983	Forecast Run Low	Forecast Run Average	Forecast Run High	Potential Catch Low	Potential Catch Average	Potential Catch High
Queen Charlottes								
constant	q=2.372	218.0	202.0	236.8	271.6	40	47	54
	q=4.132	125.1	118.6	141.5	164.4	24	28	33
	q=5.892	87.7	84.0	103.1	122.2	17	21	24
variable	q=1.223	156.6	125.3	172.6	219.9	25	35	44
	q=2.717	70.5	60.5	84.8	109.1	12	17	22
	q=4.211	45.5	40.0	59.3	78.6	8	12	16
North Coast								
constant	q=2.372	105.0	87.4	118.9	150.3	17	24	30
	q=4.132	60.3	53.9	74.0	94.2	11	15	19
	q=5.892	42.3	39.3	56.0	72.7	8	11	15
variable	q=1.223	59.0	13.9	68.7	123.5	3	13	25
	q=2.717	26.6	12.3	38.4	64.5	2	8	13
	q=4.211	17.1	10.4	29.6	48.8	2	6	10
Central								
constant	q=1.643	523.0	430.1	551.8	673.6	86	10	135
	q=3.992	213.9	188.9	237.7	286.5	38	48	57
	q=6.351	134.5	125.4	156.9	188.4	25	31	38
variable	q=1.829	373.5	305.4	398.5	491.6	61	80	98
	q=3.920	174.3	153.7	196.7	239.7	31	39	48
	q=6.011	113.7	106.1	135.3	164.5	21	27	33
Total North								
constant	q=2.372	683.0	635.0	741.9	848.7	127	148	170
	q=4.132	392.1	383.2	445.8	508.3	77	89	102
	q=5.892	274.9	278.7	326.6	374.5	56	65	75
variable	q=1.223	756.9	647.6	809.4	971.2	130	162	194
	q=2.717	340.7	318.6	390.1	461.6	64	78	92
	q=4.211	219.8	218.5	268.3	318.0	44	54	64

Table 4.4. Forecast of the 1984 runs and potential catch in tonnes (x1000) of fish for the South for low, average, and high production in relation to proportionality constant q.

Division		Spawners 1983	Forecast Run Low	Forecast Run Average	Forecast Run High	Potential Catch Low	Potential Catch Average	Potential Catch High
West Coast of Vancouver Island								
constant	q=2.235	90.8	44.9	108.4	171.9	9	22	34
	q=3.201	63.4	35.8	81.1	126.4	7	16	25
	q=4.167	48.7	30.5	66.5	102.5	6	13	21
variable	q=1.508	158.4	78.4	176.5	274.6	16	35	55
	q=2.480	96.3	54.1	114.4	174.8	11	23	35
	q=3.452	69.2	42.8	87.2	131.6	9	17	26
Strait of Georgia & Johnstone Strait								
constant	q=2.798	239.1	235.8	262.2	400.4	47	52	80
	q=3.835	174.4	172.0	232.1	292.1	34	46	58
	q=4.872	137.3	135.4	201.1	229.9	27	40	46
variable	q=4.154	211.9	200.2	229.5	353.0	40	46	71
	q=5.235	168.1	158.9	219.5	280.1	32	44	56
	q=6.316	139.4	131.7	202.2	232.1	26	40	46
Total South								
constant	q=2.235	390.2	385.8	424.3	664.6	77	85	133
	q=3.201	272.4	269.4	366.7	464.0	54	73	93
	q=4.167	209.3	206.9	310.7	356.4	41	62	71
variable	q=1.508	664.5	564.6	587.1	1033.4	113	117	207
	q=2.480	404.0	343.4	486.0	628.5	69	97	126
	q=3.452	290.3	246.7	389.7	451.6	49	78	90

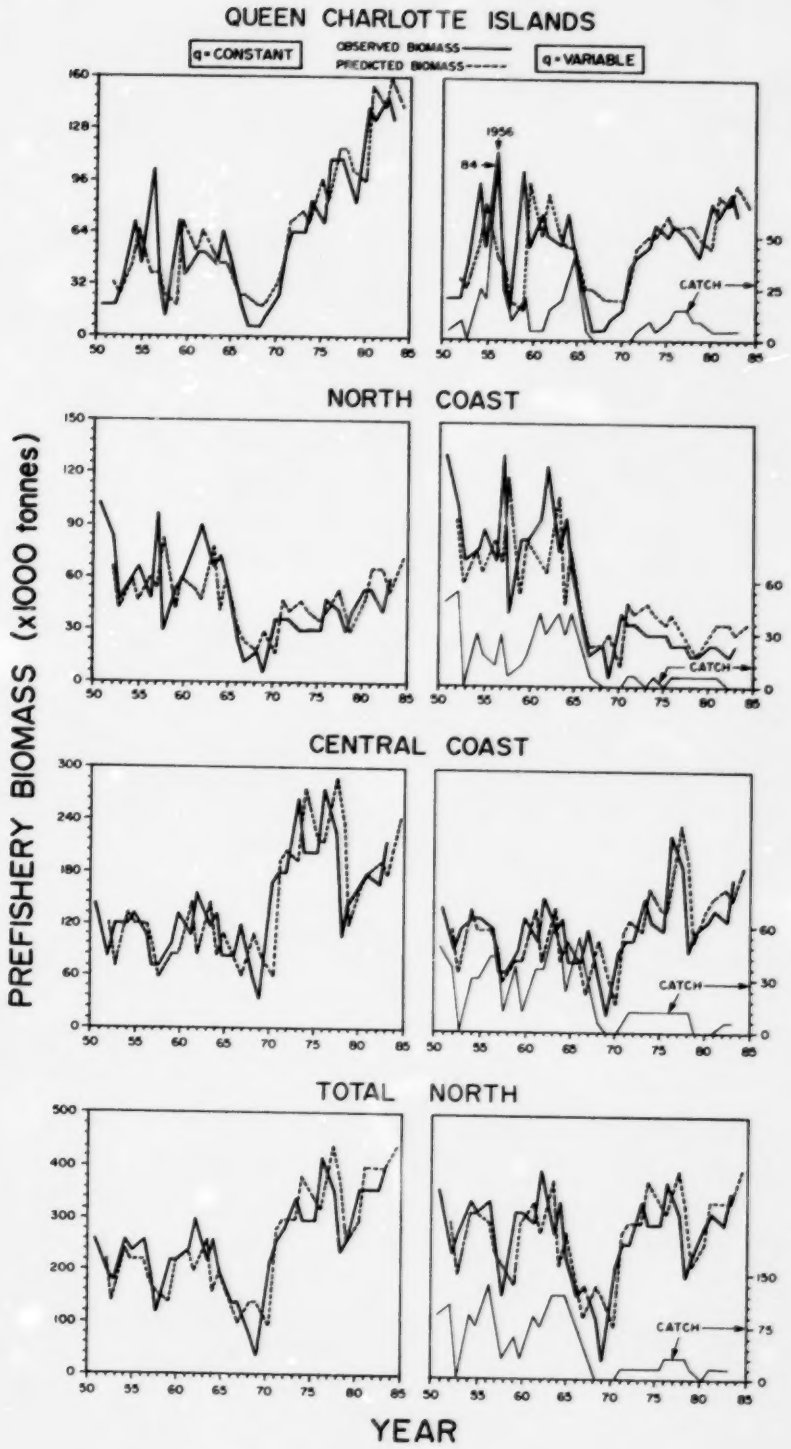

Fig. 4.1. Pre-fishery biomass for northern herring, 1951-1983.

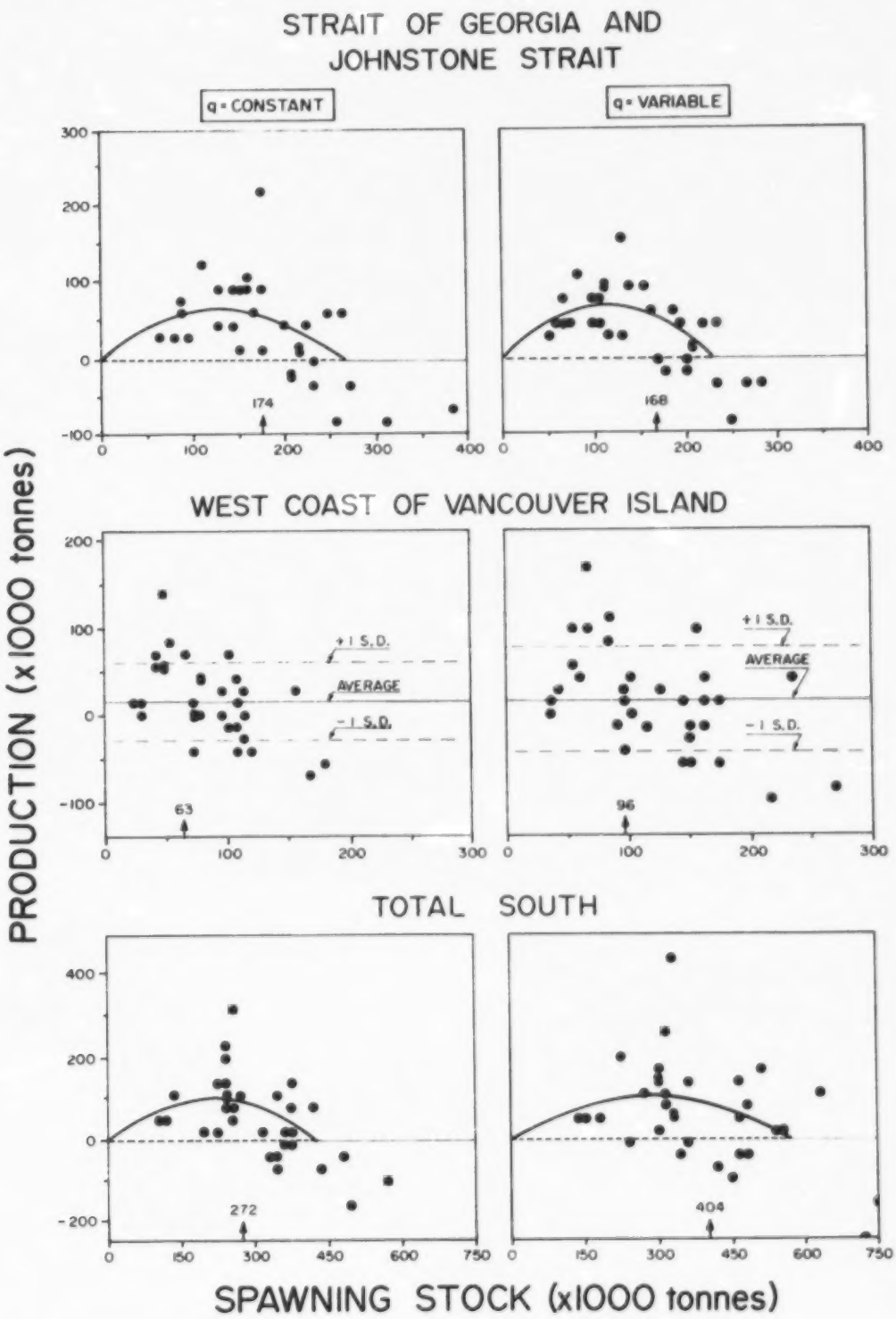

Fig. 4.2. Southern herring production, 1951-1983.

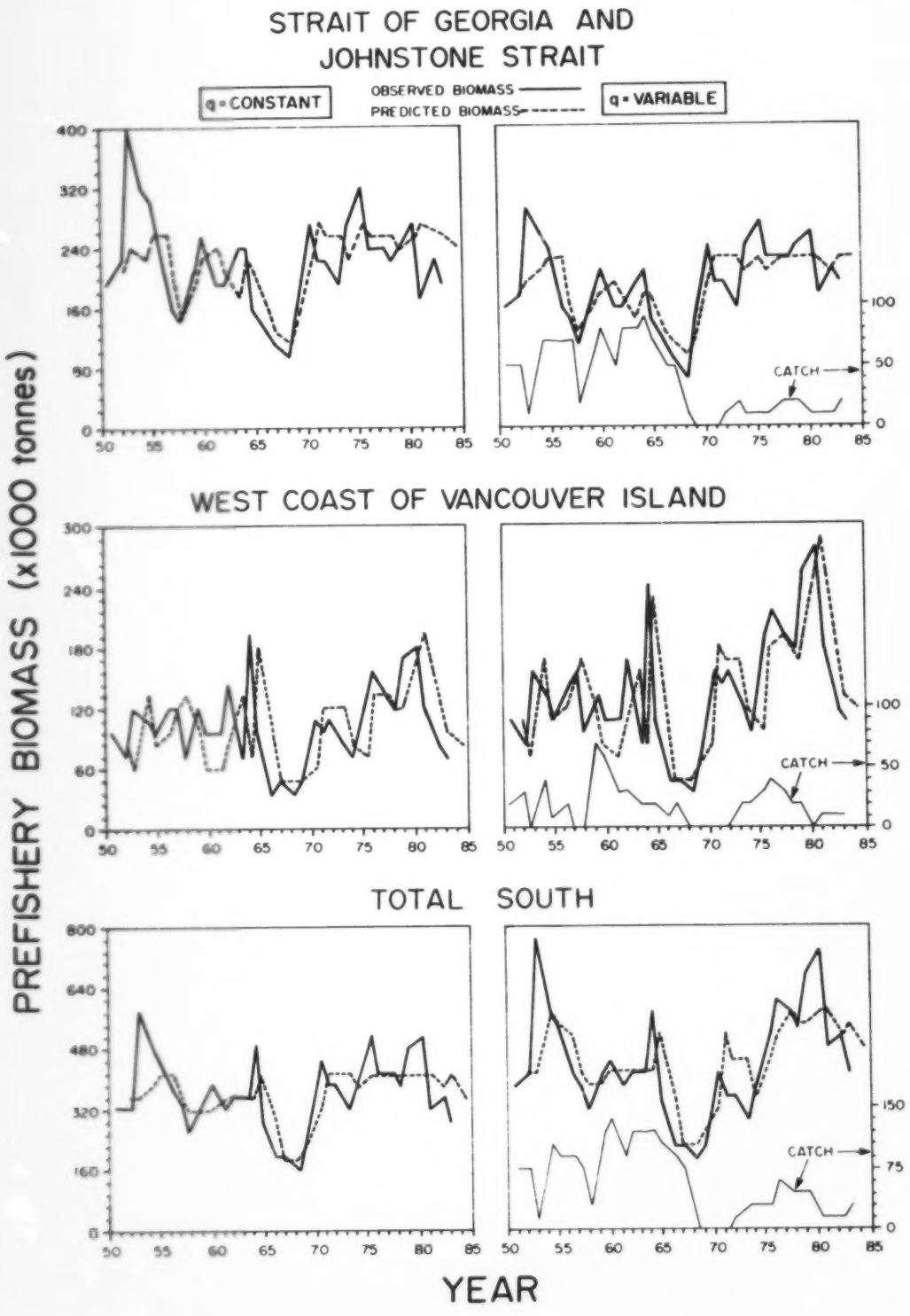

Fig. 4.3. Pre-fishery biomass for southern herring, 1951-1983.

5. CATCH RECOMMENDATIONS

In order to aid in the interpretations of forecasted runs we assigned subjective probabilities to the three alternative assessment methods. There is considerable literature on the concept of subjective or judgemental probabilities (Raiffa 1968). Based on intuition and past experience we believe that the age-structured model predicts forecast runs that may be twice as likely from those predicted by Hourston's method. Furthermore, we consider surplus production model predictions to be the least likely. We thus assigned approximate subjective probabilities or relative credibiblity to the three alternative methods as follows:

Age-structured model	p(AS) = 0.60
Hourston's method	p(ASH) = 0.30
Surplus production model	p(SP) = 0.10

The assigned probabilities were used to weight the forecast runs obtained from each method to provide a single "weighted run" for each of the stock groupings assuming average production (Table 5.1). Our final recommended catch level, are 20% of the weighted runs.

The weighted run predicted for the Queen Charlotte Islands district is 56,000 t, which at 20% harvest rate could produce a quota of 11,000 t. For the north coast the weighted run is 62,000 t for a quota of 12,000 t. The weighted run for the Central coast is 54,000 t, which could produce an 11,000 t quota at 20% harvest rate. For the entire northern district the weighted run is 145,000 t for a quota of 29,000 t at a 20% harvest rate.

The weighted run predicted for the Strait of Georgia and Johnstone Strait is 114,000 t, which could produce a quota of 23,000 t. For the west coast of Vancouver Island the weighted run is 43,000 t for a possible quota of 9,000 t. The weighted run for the entire southern district is 160,000 t, which cold produce a 32,000 t quota at 20% harvest rate.

For the coast as a whole the weighted run is 305,000 t for a possible quota of 61,000 t.

The forecasts presented in this summary are based on average productivity of stocks for 1984, and tne recommended quotas are based on biological considerations. We should point out that management of the various fisheries has practical constraints other than the biological considerations discussed in this report. Thus the final quotas recommended by the Department may differ from those determined herein. Furthermore, the quotas recommended herein include all fisheries. Catches from food, bait, and special fisheries should be subtracted from recommended quotas when roe herring quotas are established.

Table 5.1. Summary of 1984 predicted and weighted herring runs (1,000's of tonnes).

District	Method			Weighted run	20% of run
	ASH	AS	SP		
Queen Charlotte Islands	20	69	85	56	11
North Coast	29	82	38	62	12
Central Coast	37	40	197	54	11
Total North	86	134	390	145	29
Strait of Georgia & Johnstone Strait	134	84	232	114	23
West Coast Vancouver Island	47	34	81	43	9
Total South	181	115	367	160	32
Total Coast	267	249	757	305	61

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